

# The Effect of Elevated Vacuum Suspension on Axial Bone-Socket Displacement in Persons with a Traumatic Transtibial Amputation

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## INTRODUCTION

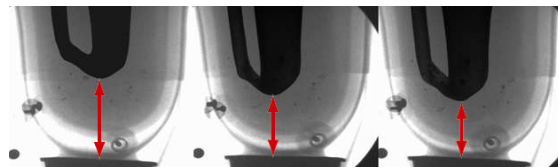
Following transtibial amputation prosthetic sockets must transfer forces from the distal prosthetic components to the residual limb in a way that will not damage the soft tissue. During walking the residual limb is cyclically loaded and unloaded producing axial bone-socket motion and undesirable shear forces on the skin of the residual limb [1]. Commonly referred to as pistoning, in active individuals the axial motion can quickly lead to breakdown of the skin in areas along bony prominences and adjacent to skin grafts [1,2]. Elevated vacuum suspension systems, which use mechanical or electric pumps to draw air from the socket, may maintain bone-socket position better than passive suction sockets [3,4]. However, limitations in the study designs and radiographic techniques make interpreting the results difficult. Digital Video Fluoroscopy (DVF) offers potential advantages over previous techniques and has been shown to be reliable for assessing motion [5]. The objective of this study was to determine the effect of elevated vacuum on axial bone-socket motion in persons with a traumatic transtibial amputation (TTA) using DVF.

## METHODS

Bone-socket motion was assessed in eight male subjects ( $30 \pm 6$  yrs,  $93 \pm 3$  kg,  $1.9 \pm 0.04$  m) with TTA secondary to trauma. Participants were assessed while wearing total surface bearing sockets that accommodated both elevated vacuum and passive suction suspension devices.

In order to replicate the loading conditions experienced during walking, the subjects applied vertical loads through the residual limb within the socket from 0 to 100% body weight (BW) in

increments of 20%. Loading of the limb was controlled using force plate data to provide auditory and visual biofeedback. To ensure consistency of loading between trials, subjects were required to be within 5% of the desired vertical load with shear forces in any direction less than 5% of the total load. Three medial-lateral digital video fluoroscopy images of the residual limb within the socket were collected at each loading condition. The distance between the distal point of the tibia and the superior border of the socket adapter was measured for each BW increment as well as 0%-100% BW (Figure 1). A radiopaque reference ruler was used to account for any inter image variability in magnification. A 2-factor (suspension type, loading condition) ANOVA and follow-up Tukey paired t-tests were used to evaluate axial displacement with the elevated vacuum on and off.



**Figure 1.** Sample fluoroscopy image of residual limb displacement within the socket during loading at 0, 60 and 100% body weight. The contour of tibia and fibula have been digitally enhanced.

## RESULTS AND DISCUSSION

A statistically significant interaction between suspension type and load condition was found ( $p=0.002$ ) so the results reported are based on the paired t-tests for each load condition (figure 2). Total axial displacement between the 0% and 100% BW conditions was significantly lower with the elevated vacuum on (ON 1.3cm, OFF 1.7cm,  $p=0.01$ ). No significant differences were found between elevated vacuum on and off for any loaded

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condition, except for a clinically insignificant difference between 80% and 100% BW (ON 0.03cm, OFF 0.13cm,  $p=0.04$ ). In addition, an approximate 0.3cm difference for 0-20% condition approached significance ( $p=0.07$ ) and would likely reach statistical significance with additional subjects. Overall, nearly 80% of the vertical displacement occurred by the 40% BW condition with both suspension types, with less than 0.3cm of displacement occurring with additional loading up to 100% BW.

## CONCLUSIONS

Our results suggest elevated vacuum systems reduce axial motion of the residual limb in the socket by better maintaining position of the limb within the socket during unloaded conditions. It is unlikely the elevated vacuum provides a meaningful improvement in limb-socket motion once 40% BW is applied.

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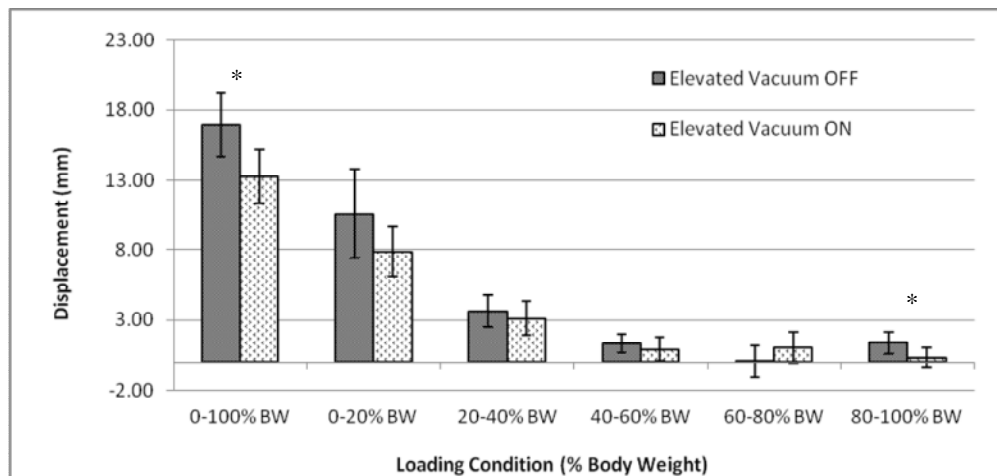
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**Figure 2.** Axial bone-socket displacement between each body weight condition with the elevated vacuum on and off. The displacement was calculated as the distance between the distal point of the tibia and the superior border of the socket adapter. Error bars represent the standard deviation for each body weight condition  
\* Indicates a statistically significant difference in axial bone-socket displacement between the suspension types ( $p<0.05$ )